Bioresource Technology 111 (2012) 155–160

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Biomethane potential of the POME generated in the palm oil industry in Ghana from 2002 to 2009

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ARTICLE INFO

Article history:
Received 16 January 2012
Received in revised form 10 February 2012
Accepted 14 February 2012
Available online 21 February 2012

Keywords:
Biomethane
Energy
Emissions
POME
CPO

ABSTRACT

The palm oil industry experienced significant improvement in its production level from 2002 to 2009 from the established companies, medium scale mills (MSM), small scale and other private holdings (SS and OPH) groups. However, the same cannot be said for treatment of the palm oil mill effluent (POME) produced. The quantity of crude palm oil (CPO) produced in Ghana from 2002 to 2009 and IPCC guidelines for National Greenhouse Gas Inventories, specifically on industrial wastewater were used in this study. During this period about 10 million cubic metres of POME was produced translating into biomethane potential of 38.5 million m^3 with equivalent of 388.29 GW h of energy. A linear growth model developed to predict the equivalent carbon dioxide (CO_2) emissions indicates that if the biomethane is not harnessed then by 2015 the untreated POME could produce 0.58 million tCO_2-eq and is expected to increase to 0.70 million tCO_2-eq by 2020.

1. Introduction

1.1. Palm oil production in Ghana

In Ghana, oil palm is an industrial crops covering about 352, 800 sq. km of land making up about 9% of the area planted for crops in 2009 (SRID, 2010). This industry has also been found to be a strong contributor to the economy (Woodhill, 2010). Since 1977 three palm oil companies; Ghana Oil Palm Development Company (GOPDC), Twifo Oil Palm Plantation (TOPP) and Benso Oil Palm Plantation (BOPP) have developed rapidly and contributed significantly towards the expansion of Ghana's palm oil sector from 1970 and 1990 and growth of about 24% has resulted in oil palm rivaling other commercial crops in Ghana (Gyasi, 1996).

As shown in Table 1, the total palm oil production in Ghana increased significantly from about 1613 Mt in 2002 to about 2104 Mt in 2009 where other private holdings contributed from 70% to 80% of palm oil production each year and medium farms contributed less than 0.5% of the total production each year.

1.2. Palm oil mill effluent management

In general, the palm oil milling process can be categorized into a dry and a wet (standard) process. The wet process of palm oil milling is the most common and typical way of extracting palm oil in Ghana. During the process of crude palm oil (CPO) extraction through the wet process, high quantities of water are utilized. The CPO process produces considerable amounts of by-products of high-energy value such as empty fruit bunches (EFB), fibers, shells, and liquid effluents with high organic content termed palm oil mill effluent (POME). A palm oil mill produces residues equivalent to almost three times the amount of oil produced by biomass on a mass basis (Arrieta et al., 2007). Table 2 shows the typical characteristics of POME from a palm oil producing industry. It is estimated that for each tonne of CPO that is produced, between 5 and 7.5 tonnes of water is required, and more than 50% of this water ends up as POME (Ahmad et al., 2003). Raw POME is a colloidal suspension containing 95–96% water, 0.6–0.7% oil and 4–5% total solids (Ahmed, 2009). Included in the total solids are 2–4% suspended solids, which are mainly constituted by debris from palm fruit mesocarp generated from three main sources, i.e. sterilizer condensate, separator sludge and hydrocyclone wastewater (Ahmad et al., 2003; Wu et al., 2009).

POME is non-toxic because no chemicals are added during a typical oil extraction process and has unpleasant odor (Ahmed, 2009; Singh et al., 2011), characterised by high organic content, high temperature as shown in Table 2, and high content of lipid (10000–17000 mg/l) (Fang et al., 2001). Since it is highly polluted wastewater (Ahmed, 2009), it can cause severe pollution of land, waterways (Singh et al., 2011; Lam and Lee, 2011) and other related effects due to its high BOD and COD levels (Table 2). However, several studies have revealed the benefits of the exploitation

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doi:10.1016/j.biortech.2012.02.065

Table 1
Palm oil production in Ghana from 2002 to 2009 (Mt) SRID, 2010.

Company	2002	2003	2004	2005	2006	2007	2008	2009
GOPDC[a]	91.6	91.5	122.3	126.5	131.2	85.4	268.9	300
BOPP[b]	90.5	91	79.2	86.3	87.4	84.4	87.7	82.8
TOPP[c]	96.1	104.9	113.8	108.7	107.7	81.8	134.1	163.5
NOPL[d]	51.4	56.6	62.2	68.4	75.3	82.8	33.9	51.0
Medium farms	4.1	4.6	4.9	5.3	5.8	6.3	5.9	6.3
Other private holdings	1278.9	1291.5	1304.4	1317.4	1330.5	1343.8	1440.58	1500.0
Total	1612.6	1640.1	1686.8	1712.6	1737.9	1684.5	1971.08	2103.6

[a] GOPDC: Ghana Oil Palm Development Company.
[b] BOPP: Benso Oil Palm Plantation.
[c] TOPP: Twifo Oil Palm Plantation.
[d] NOPL: National Oil Palm Limited.

of POME and its derivative as fermentation media to produce antibiotic, bio-insecticide, solvents, polyhydroxyalkanoates, and organic acids (Wu et al., 2009).

Some efforts have been made by GOPDC; one of the largest palm oil producers in Ghana in addressing the challenges posed by POME by testing and making use of it, instead of disposing of it via the wastewater treatment system (Stenek and Connell, 2011). The majority of CPO producers; medium scale mills (MSM) and small scale and other private holdings (SS and OPH) do not treat or reuse the POME but drain it into water bodies thereby causing environmental problems.

However, anaerobic digestion has been employed by most palm oil mills in other countries (Chan et al., 2011; Chaisri et al., 2007) as their primary treatment of POME to reduce the level of pH, BOD and COD to 7.4, 1355 mg/l and 13,532 mg/l respectively (Chan et al., 2011). The use of anaerobic digesters and anaerobic ponds has been found to have COD removal efficiency of 80.7% (Yacob et al., 2006) and 97.8% (Yacob et al., 2005) respectively. Whilst membrane treatment systems for POME has been identified to produce consistent and good water quality after treatment, with little space requirement, and disinfected treated water, membranes have short life and are an expensive technology compared with conventional anaerobic treatment systems (Poh and Chong, 2009). The anaerobically treated POME can also be subjected to aerobic treatment in order to meet the required discharge standards by using open pond or open digested tank systems (Chazaro Gerbang Internasional, 2004; Lam and Lee, 2011). In Ghana generally, POME is not treated and hence biomethane generated is not captured but escapes directly to the atmosphere and thus contributes to climate change. In 1990 about 3931 thousand metric tonnes of equivalent CO_2 emissions were released which increased to 8592 thousand metric tonnes of equivalent CO_2 emissions in 2008 (UNSTATS). Methane has been categorized as one of the GHG with global warming potential (GWP) of 25 (IPCC, 2007). Hence the objectives of this paper are to estimate the biomethane potential of the POME generated in the palm oil industry in Ghana from 2002 to 2009, to establish its CO_2 equivalent which was emitted into the atmosphere and also develop a linear growth model to predict the equivalent amount CO_2 from POME produced from the various recognized entities.

Table 2
Typical POME characteristics.

Parameters[a]	Values (mg/l)	Reference
BOD[b]	25,000	Wu et al. (2009)
TSS[c]	19,020	Wu et al. (2009)
TS[d]	43,635	Wu et al. (2009)
Alkalinity ($CaCO_3$)	50–150	Khemkhao et al. (2011)
TVFA[e](CH_3COOH)	300–500	Khemkhao et al. (2011)
COD[f]$_{(degradable)}$	55,000–60,000	Khemkhao et al. (2011)
COD$_{(Total)}$	80,000–95,000	Khemkhao et al. (2011)
Temperature	70–80 °C	Abduranhman et al. (2011)
pH	4–5	Ahmed (2009), Singh et al. (2011)

[a] All parameters are in mg/l except temperature and pH.
[b] BOD: biochemical oxygen demand.
[c] TSS: total suspended solids.
[d] TS: total solids.
[e] TVFA: total volatile fatty acids.
[f] COD: chemical oxygen demand.

2. Methodology

In addition to meeting the quality standards of POME discharged into the environment, there exists a concurrent biomethane recovery for bioenergy production. Considering the chemical contents and physical properties of POME, the most efficient system used in the initial stage of the wastewater treatment plant is the anaerobic treatment (Chazaro Gerbang Internasional, 2004) compared to aerobic treatment alone due to the biogas capture for bioenergy production (Fang et al., 2001). Additionally, the digested sludge from AD process could also be used as bio-fertilizer for the oil palm plantation (Francese et al., 2000)just as the sludge from the aerobic digestion process.

Table 3
Crude palm oil production and projections (Mt) SRID, 2010.

Company	2002	2003	2004	2005	2006	2007	2008	2009
GOPDC	19,425.00	19,956.80	26,530.20	27,065.20	28,743.10	17,842.70	18,055.68	20,143.00
BOPP	17,583.00	17,260.00	14,323.00	16,012.00	16,485.00	15,305.00	14,960.18	14,124.00
TOPP	18,688.90	19,892.10	20,588.20	20,233.60	20,348.00	14,797.10	14,249.66	17,373.00
NOPL	4794.00	5274.00	5801.00	6381.00	7019.00	7721.00	8492.83	12,775.00
AMEEN[a]	6698.00	7367.00	8104.00	8914.00	9805.00	10,785.50	11,863.68	11,000.00
MSM[b]	5729.00	6301.00	6932.00	7625.00	8387.00	9225.70	10,148.07	10,836.00
SS and OPH[c]	171,366.00	188,503.00	207, 353.00	228,089.00	250,888.00	275,976.80	303,572.32	316,222.00

[a] AMEEN: Ameen Sangaari Industries Limited.
[b] MSM: medium scale mills.
[c] SS and OPH: Small Scale and Other Private Holdings.